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ABSTRACT

Some emerging patterns in educational computing permit speculation about future trends in educational computer hardware, software, and applications. Ultimately, three types of hardware units will be used by schools: professional systems, personal computers (microcomputers), and a new generation of inexpensive personal computers that can be attached to color television sets or to their own small screens. Courseware development has been hampered by high costs and the tendency of developers to write small bits of curriculum to fit the limited potential of small systems. Significant courseware may be developed by new types of corporations with the ability to build specialized systems and to hire educational specialists to write materials. Software important to successful educational computing also includes the operating system, authoring systems, computer languages, and administrative software. Current successful educational uses of the computer include programs involving computer managed instruction, drill and practice, the concept of helps, direct instruction, cognitive diagnosis, the use of games, simulations, learner profiles, computers as a teaching language, computer literacy programs, writing and word processing programs, and administrative programs. The ultimate instructional device, however, will result from connecting a videodisc player with one of the powerful new microcomputers. (LMM)

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COMPUTERS IN ELEMENTARY AND SECONDARY EDUCATION

April 1983

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BACKGROUND

After almost 20 years of experimenting with computers in elementary and secondary schools, the leaders of Computer Assisted Instruction (CAI) have begun to perceive some discernible patterns. We can now speculate with reasonable confidence about some issues such as what types of hardware will be used by schools, what tasks the computers will accomplish the most effectively, and what the educational courseware will be like.

Currently there is a great deal of confusion both in professional educators' minds and among the public about the apparent direction CAI will follow. Schools are being innundated with inexpensive microprocessors, and most people assume that this is the direction that will be commonplace in the future. In fact, the flood of personal computers is not necessarily a clear picture of what will be happening in the years ahead. Those people who have been following the field for almost 20 years recognize that there will probably be at least three separate types of hardware in the schools, and each will have a specific function and purpose. It is important that school administrators, teachers, and those interested in education understand the underlying trends of the field so they do not become confused and disillusioned with the apparent limits of the first wave of computers. They must understand that there will be excellent options that soon will be available to allow for more to be accomplished in the schools. In order to understand the evolving trends, we must analyze some of the component parts.

HARDWARE

Generally speaking, there will be three types of hardware that schools will use:

(1) Professional systems that will run 30 or more terminals simultaneously with audio, graphics, and animation at each work station. The price per work station of the professional systems will be $2,500 or less.

(2) Personal computers such as the IBM, Apple, Atari, Commodore, and Radio Shack machines. The personal computers usually will have diskettes for storage, and retail in various configurations from over $3,000 per work station, down to about $750 including a terminal.

(3) Beginning in the latter part of 1984, there will be a new generation of personal computers that can attach to color television sets, or to their own small screens, which will retail for $250 or less.

(1) The Professional School Systems:

Professional school systems are being built around powerful minicomputers or the new microcomputer families such as the Motorola 68000 chip. They have a number of distinct advantages over the personal computers:

- They can combine the use of administrative software with educational software. This allows the school district to use the same computer for both administrative purposes as well as educational ones.
- They will have large and powerful disk drives that will store student records and enable the faculty and admini-

stration to keep track of student performance and problems. The cumulative records will have great value in helping teachers become acquainted with the past performance of their students so they can track their patterns.

- The professional systems will have enough power to allow the use of professional authoring systems for the schools. Professional authoring systems allow teachers who know nothing about programming to write interactive instructional materials, with graphics, animation, and audio. Authoring systems have been in development for over 15 years, and a professional system can support an outstanding one that will be of great help to a school, or a school district, in developing its own instructional units, or supplementing or modifying the course materials already on the system. Even students enjoy learning the authoring systems and gaining the freedom to develop materials without actually programming them in a specific computer language.

Authoring systems are particularly useful because they avoid the problems that schools have always faced in trying to code instructional programming with professional programmers. Large instructional programs written by professional programmers are not only expensive to develop, but are very time-consuming and even more expensive to debug as the coding errors are removed. Even more importantly, they allow the instructional materials to be changed to fit student response. Instructional materials are developed in an iterative fashion

where they are tried, modified, tried again, and modified, etc. This type of modification puts tremendous strain on the programmers when they are writing in professional languages such as FORTRAN or PASCAL. They dislike making changes because it introduces new rounds of bugs, or errors, in the programming. Frequently programmers become burned out and disturbed because of the constant changing of instructional materials. Then, once they leave, there is an expensive delay in making future changes as new programmers try to understand their cryptic code.

An authoring system gets rid of all these coding problems because the computers write the code automatically, and any change can be made very quickly without producing any errors in the code. This allows the educational materials to be developed quickly and less expensively, and also avoids the potential trauma of having a developer trying to interface with the programmer who does not want further changes in the materials. In fact, this frees the developer to work directly with the system even though he or she may know nothing about programming whatsoever. A good authoring system only requires a few hours of good instruction before the developer can begin to produce decent materials.

- A professional system helps reduce the need for extensive faculty training before the computer can be used effectively. Traditionally, what happens is that a 30-terminal cluster

is put in one room, allowing a whole class at a time to take instruction, and the class is supervised by a paraprofessional who has been trained in how to run the various programs. The faculty are free to turn the students over to the paraprofessional, so all of the faculty does not have to be trained before the system can be useful. Gradually the paraprofessional will work with the individual faculty members to bring them up to date on how the system is helping their students and to teach them how to gain useful information from the various reports being generated by the computer-managed system.

- The professional system is able to provide outstanding computer-managed instruction (CMI) for the faculty members and the administration. These packages allow every student to be tested and tracked through all of the course materials being taken on the computer. The information is invaluable to individual faculty members who now have an opportunity to follow in great detail the progress and needs of all their students without having to run time-consuming tests and grading them.
- The professional system has the capability to provide excellent audio and speech at each work station. The quality of speech is such that the person speaking can be recognized, as it avoids any of the artificial-sounding robot-type of speech used on the personal computers. In order to have enough speech stored for real instructional value, a large disk must be used which only the professional systems have. This audio is necessary to teach reading,

foreign languages, and English as a second language for foreign students.

- Another great advantage of the professional system over the personal computer is that it is much more productive of the users' time. In preliminary evaluations WICAT has discovered that handling diskettes on personal computers takes a great deal of time for the students before they get the appropriate lesson material on the screen. A professional system will produce the material almost instantaneously for a student because he need not handle any disk or storage materials. In some of our preliminary research we found that there is a 50 percent improvement in using a professional system for learner productivity.

This learner productivity is significant to teachers who do not necessarily want students away from class working on computers for too long a period. A good professional system can have an entire class log in almost instantaneously and then have very productive interactive instruction with different materials at each work station so that the student can learn a great deal in a 10 to 20-minute session. Furthermore, the professional system will keep records of everything being done by each student for further analysis. Using diskettes, or waiting for small networks to download materials from their disks to the personal computer would probably require a 40-minute period to do what a professional system can do in 20 minutes, particularly if any management records are trying to be retained

and integrated with the instructional system.

- Probably the most significant advantage of the professional system is that it is the only one which currently can allow serious instructional materials to be used in a comprehensive instructional mode. It takes a great deal of power to drive excellent audio, graphics and animation, and natural language answer processing. By natural language processing, we mean giving the student the ability to type an answer in an unstructured fashion, such as a sentence. The power of the professional system can then analyze the sentence that the student has typed in to see if it has the proper answer. Furthermore, fault-tolerated spelling algorithms can also be implemented which would analyze the answer to see if the answer is correct even though it might be misspelled. Having sufficient computer power to do this is important because otherwise students get disturbed when they think they have typed the right answer and the computer keeps saying 'no.' The student can accept a comment that says, "Your answer is correct, but please note that your spelling of the word _____ is incorrect."
- The power of the professional systems will enable a whole new diagnostic field to be developed for students called the learner profile. A learner profile is a series of extremely sophisticated tests, with such features as audio, graphics, and animation, which tests the student to see what their individual learning profile is. For example, it will identify whether the student has a learning disability such as dyslexia, or it may print out that the

student has hidden talents that should be developed in such areas as foreign languages. Alternatively, it might identify the individual students' personal learning decay rate and alert the student to when he or she should do some reviewing of the materials in order to retain them in memory. It might also comment on individual learning styles and suggest alternative approaches to helping the student try methods that might be more effective. The development of a comprehensive learner profile should be of great value to parents, teachers, guidance personnel, and the students themselves.

- The professional system would be ideal for connecting videodiscs to individual work stations that will allow the full use of the computer interacting with the videodisc. Smaller computers can control the videodisc without great difficulty, but usually they lack the power to allow rapid overlaying of graphics and animation on the videodisc frame that is being presented to the student. This ability to mix computer graphics and words with the videodisc frame is significant in educational usage. Without this ability, the videodisc frame remains a static image which cannot fully interact with the student.

(2) Personal Computers

Schools will not make a mistake in starting their computer programs with some personal computers. Even if they purchase a professional system later, the small systems can be useful in complimentary activities. The cost per work station will

not be dramatically different from the professional systems, but they will allow a school to get started with just a few units rather than purchasing the entire professional system at once. Thus schools are purchasing hundreds of thousands of these small systems with either one or a few personal computers per school. Their strengths are numerous:

- They are portable and inexpensive, so they can be moved about the school and shared without stress. A school can get a few of these computers with a minimum of financial investment.
- A number of publishers are producing some good textual materials to support their courseware. This textual support, and potential training of the faculty with formal seminars and classwork, will be very helpful to the schools.
- They are excellent in teaching students computer literacy. This is the primary area that publishers have decided to penetrate in the elementary and secondary markets. Thus students can get a general introduction to what a computer is, and with the help of the textual materials, they can become literate in the implications of using a computer.
- Personal computers are also outstanding for teaching computer languages or computer science. This is a sound use of the computers because students very much need to learn to program in a school, or home setting.
- Although serious curriculum packages are restricted by the power and storage of the system, some excellent discrete instructional units and games have been developed which can help motivate students.

Thus personal computers are inexpensive, easy to get started with, and offer distinct advantages in teaching computer literacy and computer programming. In doing these jobs, they are well supported by textual materials from publishers.

Their disadvantage is that they lack adequate storage and power to do in depth professional instruction, so they will not be of great help in improving the instruction of the standard basic courses that a school traditionally specializes in. They will be of help in getting students familiar with computers and teaching them to program, but in a sense this means their instructional contribution is restricted to offering a new discipline to the school, i.e., computer programming, computer science, and computer literacy, rather than helping solve the great national need of making the older disciplines more effective, i.e., English, reading, mathematics, science, foreign languages, etc.

There are a number of disadvantages that are a function of the lack of power in these machines:

- The audio capability if any, is inferior in quality.
- Any authoring systems that can be developed for these personal computers are so rudimentary that they contribute little to helping the instructional process.
- The CMI potential of these systems (Computer Managed Instruction) is minimal because of the power and storage restrictions.
- Similarly, keeping student records is difficult, at best.

- The school is unable to use the systems for serious administrative use. There have been some modest administrative units developed, but they are too restrictive because of the lack of power and storage.

(3) $250 and Less Computers:

There are some individual units out such as 'Speak and Spell' and other specialized educational devices that cost less than $250, but they tend to be underpowered and rather restrictive in their software offerings. By late 1984, there will be a new generation of these small devices which will have much more powerful 16/32 bit microprocessors in them. This will allow serious educational software to be developed for these devices. Many of them will be sold to the consumer market to connect to the television sets. WICAT is investing $15 million in a product line of educational software for these new devices. Many of them will contain ROM cartridges with educational software embedded in these cartridges, somewhat similar to the game cartridges.

Schools will be able to use these devices for some serious curriculum instruction, and because they are so inexpensive, a few can be purchased at a time to connect to an inexpensive black and white monitor or color television set. By late 1984 or early 1985, laser videodiscs will be making a resurgence in the market, and in all probability these inexpensive new devices will have an option to control the videodisc player as it plays its contents on the color television screen.

These new devices will have a number of advantages over the personal computers:

- They will use the much more powerful processors that will enable serious educational courseware to be used on the machines.
- In conjunction with the videodisc, they could offer outstanding audio, motion picture sequences, color photographs, or individual frames of graphics and text.
- Because they are inexpensive they will allow a school to use the devices in two ways:
  - They can use them in individual classrooms for instructional use.
  - They can have the children check out the units to be used at home in supplementary homework.
- In some cases these units will be able to attach to the larger professional systems for the purpose of keeping student records.
- Since the course materials will be stored in standard plastic cartridges, the reliability of the units should be quite high. Currently floppy disks can store more than the ROM cartridges, but since there is a great deal of mechanical wear and tear with floppy disks, the reliability is not as high. Where more storage is required or the ability to store new materials is needed, the new inexpensive units will also have options to have the small floppy disk drives attached.
- The inexpensive computers will have excellent color graphics capabilities on color television sets, and since they

will remind many students of game cartridges, these new units should be attractive to the student population.

There will be some disadvantages with these smaller units:

- At least for the foreseeable future, the quality of audio will be somewhat limited except when hooked to a videodisc player.
- Since most of the serious educational materials will be in cartridges, they will not be as useful for teaching computer science or languages as the personal computers that generally have floppy disks and good instructional manuals available. At some point in the future with the addition of floppy disk drives, these small units will be able to do some of the same computer literacy tasks and language training as the personal computers. But for the foreseeable future, the personal computers will have a lead in this area because of the substantial investment in literacy and programming software that the publishers and personal computer companies already have.

Summary of the Hardware Situtation:

Ultimately there will be three types of units used by school systems. They will have professional systems that offer ideal instructional and administrative software and can be used to maximum advantage for student productivity. These professional systems will be ideal in every way for a school district, but they will require a larger initial financial commitment than buying a few personal or inexpensive new computers at a time.

The personal computers will continue to be useful for teaching computer programming and computer literacy. They will also run small software packages that will do pieces of instruction quite cleverly. Where they fail is that they lack the power and storage for serious instructional usage. Fortunately, a new generation of inexpensive devices will be coming in late 1984 or early 1985 that will have far more power, and hence will have serious instructional capabilities. Thus schools will be able to buy a few of these at a time and have excellent instructional courseware available. But since these units will use cartridges for the most part, they will lack some of the capabilities of the personal computers and larger systems for storing materials on disk drives, etc.

Thus it is likely that schools will begin by purchasing a number of personal computers, and then having matured in their understanding of the system, they will begin to purchase some professional systems to help improve their instructional effectiveness. They may concentrate initially in these areas where they lack adequate teacher support, such as English as a second language for foreign speaking students, advanced mathematics, foreign languages, etc. Then to complement their professional systems, the schools will begin to purchase the new generation of very inexpensive devices with the more powerful microprocessors in them. This will allow them to add incremental units when the capital is available without a large intitial investment, and it will also start a new tradition where the schools will begin to use the inexpensive devices for supplementary homework for their students. Many

school districts have learned that without parental support, they are unable to make dramatic changes in instructional effectiveness. A number of districts have already started plans to purchase thousands of the smaller units that will be used to supplement the school efforts through home usage. They also are planning to train the parents for a few hours in how these new technologies can be used with parental support and encouragement.

COURSEWARE

The development of instructional materials, technically called courseware, for computer systems has not been very effective up to the present time. The reason for this is not commonly understood. The real problem is that the development of a typical course such as Algebra I or French I costs approximately a million dollars per course. This figure has held constant for almost 20 years. As we have learned more, we have been able to develop the courses for less money, but inflation has made up for whatever efficiencies the learning curve generated.

Since there have been only a few instances where developers have been able to spend a million dollars per course, there is very little useable courseware. The advent of the personal computer has exacerbated the problem because it lacks the power and storage required for serious courseware presentation, and hence courseware developers have tended to write small bits of curriculum to fit the potential of the small systems. Thus if one were to purchase all

of the diskettes currently available for instruction on Apple-type computers, one would find some interesting pieces of curriculum, but with rare exception (and this primarily in drill and practice in elementary math) there are very few full courses developed.

Those courses that have been developed fully relate almost exclusively to the elementary school. Some exceptions are the TICCIT and PLATO projects. In the early 1970's the TICCIT project developed an excellent mathematics course for the junior college level at an approximate cost of a million dollars, but this course has never had an impact because it was developed on a special system that has never been purchased by any subsequent schools. Similarly, the Control Data Corporation has developed some advanced units in physics and mathematics that will only run on very expensive large computers. For the most part, these are incomplete courses, but some of the units are excellent. Currently Control Data is translating some of this courseware to the personal computer, but much is being lost in the translation because the original materials were developed for large computers with many more features and greater power and storage.

Patrick Suppes of Stanford University had extensive government and foundation funding from 1964 through the early 1970's, and he was able to spend millions of dollars on some course materials. He set the early standards for the use of drill and practice in mathematics and in language arts, and he has had a considerable influence in the field. His materials were then transferred into a company called Computer Curriculum Corporation (CCC) which has

been marketing microcomputer systems to schools for almost a decade. Suppes' materials for the most part are restricted to the elementary school level.

WICAT Systems is a new company that is specializing in developing educational hardware, software and courseware. By late 1984 WICAT will have invested approximately 25 million dollars in development, most of it for educational courseware. The corporation estimates that completion of a full scale effort for both the consumer and school markets will require up to an additional $50 million before sufficient courseware will be developed for both professional systems and the new inexpensive home computers costing $250 or less. WICAT is currently offering a broad line of elementary courseware in the basic skill areas on its professional system, and over the next few years will be adding high school and college materials. By late 1984 the corporation will also have many basic skill areas developed for the new inexpensive micros having the powerful 16 and 32-bit computers for the consumer market.

The development of these materials is not a simple task because it requires a battery of specialized experts including:

- Skilled administrators as project directors
- Subject matter experts in the academic disciplines
- Instructional design experts who know how to take the knowledge of the subject matter experts and develop sound instructional materials
- Programmers to aid in the program development
- Writers to develop the specific materials designed by the instructional design teams

- Editors to edit the materials and produce textual versions, user's guides, and teacher's guides.
- Artists and graphic artists to develop the graphics.
- Testers to facilitate the debugging process
- Clerical and secretarial help
- In the case of videodisc development, production personnel, film makers, still photographers, and audio experts are required as well.

In addition to the development of the courseware itself, there is a substantial additional programming task to produce computer management programs for the instructional materials. These programs keep student records, monitor student progress, give progress reports to the faculty, and allow teachers to turn instructional options on or off in the student lessons. In some cases, for example, teachers might not want students working on games after they have finished certain mathematics units. These games could be shut off by the manager.

The reason courses cost a million dollars is that they require substantial staffing of expensive personnel for an extended period of time before all of the complicated elements can be completed. WICAT has gathered approximately 30 Ph.D.'s who are working on instructional projects. Keeping this talent level properly supported is an expensive activity.

This expensive development cycle has proven to be a serious problem for publishers because, in general, they are seriously under-

capitalized and lack funds for extensive R & D. Traditionally, they have used authors to write the materials for free, and then they have spent their resources on editing, packaging, and marketing the materials. In a sense their R & D is publishing many books, many of which will be commercial failures.

The computer manufacturers, on the other hand, are interested in placing hardware in the schools. Up to 15 percent of some of their sales have been to the schools. For this reason they write very colorful booklets and have pieces of curriculum developed to try to attract additional school purchases. But they lack the interest, the skill, and the commitment to invest millions of dollars in educational courseware. In fact, they would not understand how to do it because they are interested primarily in selling hardware and are not apt to have the in depth collection of educational experts necessary for a 5 to 10-year development cycle of a solid educational library.

WICAT believes that the really significant courseware will be developed by new types of corporations similar to WICAT. These are corporations that are interested primarily in education, but have the ability to build specialized hardware, develop special software and courseware, and retain educational specialists to write the materials. The large amount of capital required for the development will probably only be available through the newer kinds of high tech companies because investors are willing to invest heavily in these rapidly growing companies.

SOFTWARE

The term "software" is used in two ways:

(1) to describe programs that allow the computer to run, but have no specific value except to programmers.

(2) to describe programs that serve end users, such as word processing, financial programs, educational programs, etc.

In industry, the second use is delineated by calling the software an "applications package." In education, the tradition is to separate out the applications packages that teach specific courses and call them "courseware." School software applications, such as administrative packages or testing programs, are still called "software." Only the course materials are called "courseware."

Although the end user frequently is not aware of it, the quality of the software attached to the hardware determines, to a considerable degree the success of the courseware effort. For example:

- Fundamental to every computer is a software program called an operating system. This is the program that serves as a link between the application programs (in this case, education) and the special machine languages required to operate the computer at a maximum efficiency. It takes years to develop a good operating system and millions of dollars. WICAT has been working on its operating system, for example, since early in 1979 and has had a large team of programmers developing it and improving it since then. Personal computers

traditionally not only lack adequate computational power, but are also saddled with rudimentary operating systems. For this reason, all of the significant courseware that has had an educational impact has been developed on larger machines. The new generation of the powerful microcomputers, such as the Motorola 68000, has enough power, when supported with sophisticated operating systems, to allow serious courseware development to take place.

- Another piece of software which is fundamental to developing excellent instructional materials is an authoring system. In the late 1960's and early 1970's a number of authoring systems were developed by large companies such as IBM. These early attempts were partially successful, but only allowed certain rudimentary instructional interactions to take place. They also lacked the ability to allow graphics, animation, and audio to be used. In order to be effective, an authoring system must have access to both a powerful operating system and a powerful computer. The user is then able to use many sound instructional attributes such as a spelling tolerant feature which will accept correct answers that have been misspelled.

- Other useful software for serious educational usage relates to computer languages. These languages help the student learn the discipline of the computer science itself rather

than other traditional disciplines such as English. The languages may be used as a tool to develop other instruction, but in and of themselves they are significant for helping students to understand about computer programming.

Some languages have been specifically developed with instruction as the central theme of the language. For example, Semour Pappert of MIT has developed an excellent mathematical language called LOGO. This language helps the students to think mathematically and to use many concepts of mathematics while using it. The language can also be used for creative graphic development which can illustrate some of the fundamental mathematical problems behind even the most beautiful of objects.

In 1965, Kemeny and Kurtz of Dartmouth College developed the BASIC language to help students learn programming quickly. The advantage of BASIC is that it helps students to learn computer programming rapidly, but it has its critics because it has some programming conventions that are currently frowned upon by computer scientists. They feel that these conventions encourage bad programming habits. Some critics also feel that BASIC, in its simplistic approach, does not encourage students to think about certain concepts of programming that are important because BASIC

does not even allow those statements to be used because they never have been programmed into the language.

A more recent language developed for teaching students about programming is PASCAL. PASCAL is probably the most commonly taught language now in serious computer science departments in the country. It has the new conventions, specifically something called "structured programming."

An earlier language developed for scientific computing called FORTRAN continues to be very popular in the physical sciences, and businesses use a language oriented for their needs called COBOL. COBOL is not normally taught as a serious computer language because its strengths are limited to very common business applications. Thus most computer science departments will not teach COBOL except to potential data processing students who would be hired for application programming in COBOL by industry. Despite the negative attitude of the profession to COBOL, a vast majority of all programs developed are written in COBOL.

For the newer science of artificial intelligence, there is a language called LISP. Students will be using this language in the future a great deal more as this field matures. Finally, one of the most interesting languages to some computer scientists and certain mathematicians is a language called APL. APL has remarkable power in

its terse statements, and hence is treasured by many users. But it has the disadvantage of being so cryptic that it is difficult to come back to an old APL program and modify it because it is not easy to understand or modify its concise statements.

Summarizing this point about the computer languages, we would note that schools will all want to teach computer languages to their students, so it is important that the various computers available have a number of languages. The personal computers have developed reasonable subsets of many of the languages, although most of them use BASIC as their standard. The larger professional systems will have a broader range of languages available for the advanced computer classes.

- Administrative software is extremely important in helping aid the cause of instructional computing because its availability encourages the school administrators to acquire hardware for the schools. Traditionally the administrative packages have been purchased on large main-frame data processing machines that are not related at all to the instructional sector of the schools. The personal computers have lacked the power and storage to do serious administrative work, although some nice support programs have been developed for some administrative needs such as a financial spread sheet.

Here again there will be a distinct advantage in using the new professional microcomputer systems because for the first time we have truly multi-functional machines available that can combine administrative and instructional usage. While students are taking instruction in math, for example, secretaries may have word processors connected to the same system while the registrar updates grades and attendance records, and the financial office runs the payroll. These multi-functional machines will also have the capability to communicate back to district sites who will be able to keep track of student attendance and performance, as well as the financial affairs of the individual schools. WICAT has developed a broad range of administrative programs that are run concurrently with their educational programs on their new professional system.

SOME TYPICAL USES OF COMPUTERS IN SCHOOLS

Computers are being used successfully in at least a dozen different ways in elementary and secondary school settings. Some of these are:

(1) Computer Managed Instruction (CMI). During the late 1960's when the first attempts were made to implement computers in schools, the only area to survive commercially was Computer Managed Instruction. The computer manages the instruction by keeping track of individual student performance. It can then assign the student specific instructional tasks to keep

track of student performance. In addition, it is very useful in helping the teacher stay on top of the different levels of mastery being achieved by the diverse class which he or she is trying to teach.

A good rule of thumb to understand the differences of abilities in a typical class is to say that the grade level is equal to the academic spread in that particular class. In the fourth grade there is apt to be four years of difference among the students in achievement, and by the 8th grade, 8 years of difference. Thus in the 8th grade class, one student might be reading at a fourth grade level while another is at 12th grade level. Because of the extraordinary amount of work a computer can do, it can follow these differences of all the students, keep the teacher informed, and make appropriate assignments for each student. It also can keep the administration informed as to the general progress of either an individual student, a class, or the school population as a whole.

One of the reasons that CMI was successful in schools is that it was correctly perceived by teachers to be a very supportive and helpful device in managing their classes. It did not threaten them by pretending to offer parallel instruction, and it definitely helped relieve the work load of the teachers in grading papers and trying to follow the achievements and needs of the individual students. The most successful practitioner of CMI commercially was Westinghouse Learning

Corporation. Now CMI is offered with most instructional packages, but when used with diskettes, it takes a great deal of time and effort to manage the disks successfully. In the future, the CMI packages will be extremely helpful to faculty members when they are linked to serious instructional materials. They will be the link between the classroom teacher and what is going on in the computer center where the students will be taking their instruction a class at a time. They will keep the faculty appraised of all the students' performances, and it will enable them to spend more time individually with some students when areas of concern are brought to the surface.

(2) As the field developed, <u>drill and practice</u> became the next commercially viable area to be developed. The great pioneer of this work was Patrick Suppes of Stanford University. Traditionally critics of CAI have downplayed the value of drill and practice and tend to attack it as being too simplistic. They miss how sophisticated a simple drill and practice program really is. The great contribution of the computer is that its power can bring a level of intelligence to the work station that will interact with the student while taking him or her out of a passive role. On drill and practice, for example, there are many acts of intelligence. First of all when the student logs on, the computer recognizes who the student is, looks up the student records, sees what instructional materials should be presented, and then presents them to the student.

After it presents the material, it waits for the student's answer, and then judges whether it is correct. Then if the student misses the problem twice, it supplies the correct answer to the student. In another act of intelligence, the computer then judges how the student is doing with a particular level of problem after the student has taken a number of them. If the student is missing too many, the computer automatically gives easier problems until an appropriate level for the student is reached. Once the student has obviously mastered a particular set of problems, the computer automatically increases the difficulty level to keep the student challenged. At the end of the lesson, the computer tells the student how he or she has done, and then stores the records of all the student's actions in an appropriate file for future reference by the teacher. Thus even in a simple drill and practice program, there is a great deal going on that can be of help to the student.

The real instructional reason the drill and practice approach seems to be so effective is that it provides a great many trials with feedback on an individualized basis within a given time frame. Thus it removes the student from being a passive observer in the class to an active participant. Research has shown that students can make considerable gains in basic skill areas with only ten minutes a day of drill and practice. Apparently the number of trials with feedback in that 10 minute

time slice far exceeds what a normal classroom can offer, and hence it improves the mastery of the subject matter significantly.

Drill and practice is now the general approach being offered on most of the personal computer software.

(3) The concept of helps. A new addition to the drill and practice programs which adds a whole new dimension to their instructional effectiveness is the concept of adding a "help" to each problem. After a student misses the first try, the computer asks the student whether he or she would like another try, or to receive help. Should the student decide to try again, and then misses again, the student is not given another choice, and a help sequence is automatically initiated. The help sequence acts as a personal tutor for the student. When called in, the help clears the screen and reprints the problem the student has missed. It then graphically breaks the problem apart with animation, highlighting, and various prompts, and leads the student interactively through a step by step solution of the problem. This personal tutor adds dramatically to learner productivity because it enables the student to receive specific help in a tutorial mode without having to find and wait for a proctor or a teacher to help clarify why the student has missed the problem. WICAT has pioneered in the use of helps and routinely appends them to its instructional materials.

(4) Direct Instruction. Very little direct instruction has been developed in computer assisted instruction because of potential faculty resistance to the approach. Some faculty have indicated some concerns because they do not want to have students getting ahead of the rest of the class for fear they will have bored students on their hands when they attempt to present the new materials. They also have reservations about direct instruction that might contradict the approach that they are using in their teaching. In math, for example, they might be teaching mathematics around set theory while the computer program teaches a more classical approach. At this point in the evolution of CAI, students can have the equivalent of instruction by using the drill and practice materials with helps. But in the future it is inevitable that significant direct instruction will be developed.

(5) Cognitive Diagnosis. Dr. John Seely Brown of the Xerox Palo Alto Research Center (PARC) has done some extremely original work in cognitive research in student learning patterns. He has found that there are standard "bugs" in student procedures which can quickly be identified and unraveled. Normally a student has inadequate time with a teacher to identify his or her bugs. For this reason a student can develop poor habits with some serious bugs that cause constant confusion in future learning attempts. In mathematics, for example, the problem below illustrates two of the most common bugs:

$$\begin{array}{r} 127 \\ -\ 90 \\ \hline 170 \end{array}$$

A student doing this subtraction problem is not concerned with the irrationality of getting an answer of 170 which is larger than the number being subtracted from, 127, because the student is concentrating on following a cognitive process which he thinks is proper. In computer jargon, the student is following some "algorithms" which are faulty. The first bug is what is commonly called the "zero bug." In a zero bug the student takes "0" from a number and makes the answer "0," illustrating confusion as to what "0" means, and what the proper cognitive procedure is in subtracting "0" from a number.

The second bug is commonly called the "lesser from greater" bug. In this problem, the student has tried to subtract 9 from 2 and recognizing that this can't be done. Instead of carrying a "1" over to make it a "12", the student reverses the procesure and subtracts "2" from "9," giving the answer of "7." In the third column, the student correctly brings the "1" down, and thus is left with the answer "170."

In the future, sophisticated diagnostic programs will be developed that look specifically for these cognitive errors or bugs, and when it finds them, will quickly straighten the

student out so that the correct algorithms or procedures are implemented in the student's approach to problem solving before bad habits become solidified.

(6) The Use of Games. Many of the programs being sold on the personal computers have interesting game features. Games are particularly apt for helping to motivate the students to interact with the computer. What will probably happen is that the student will be allowed to play with games that have instructional value in short sessions following straight instructional efforts. They will be used as a reward for having accomplished a set number of standard learning tasks. There is also a good chance that many games will become so educationally useful that they might be used as straight supplementary materials for standard courses. This is a relatively unexplored area of CAI, but it seems to hold great promise for improving student motivation.

(7) Simulations. Complex simulations will be used to help arrange learning experiences that are difficult to set up in a school because they might be too dangerous, or they might take too much time to complete under normal circumstances. For example, using graphics many science simulations could be run in chemistry. Donald Bitzer, who was instrumental in developing the PLATO instructional system at the University of Illinois, has overseen some exciting work. Chemistry flasks and other

various chemical apparatus are portrayed on the screen. Using these programs students can run simulated chemical laboratory experiments without having access to a laboratory.

Some laboratory experiments could be too dangerous for normal supervision, and the computer will offer a capacity to simulate these experiments.

In other situations simulations are helpful in imitating complicated experiments such as calculating what would happen to a butterfly population that had protective coloration in its environment vs. non-protective coloration. As one town industrialized and filled the air with dark soot, all of the white butterflies were quickly killed because they could be spotted so easily by predators, while the dark butterflies began to multiply dramatically.

Nobel prize-winning experiments can be simulated such as the Milliken oil drop simulation. Here students can change the variables to study the results without having to have the laboratory apparatus. Similarly, extensive experiments in photosynthesis can be simulated where variables can be changed and the students see the results quickly without having to go through the laborious process of changing the variables over many months.

Dramatic results can also be shown in genetic simulations.

Bitzer has done an outstanding simulation on some genetic experiments with bees where the results are printed out presenting the actual physical appearance of the bees as they are bred through different generations.

Dr. Lud Braun of the State University at Stonybrook in New York has developed an excellent series of simulations for inexpensive microcomputers. These make some fine supplemental materials for standard courses. Ultimately, however, as the professional systems enter the marketplace, the laboratory simulations will be appended to the standard instructional materials. This will enable students who do not have outstanding science teachers or facilities available to receive first rate training.

Simulation can also be used in many areas besides science. For example, economic modeling packages will allow students to simulate various business decisions and understand the implications of those decisions. Students can be given a company to run, such as a ski company, and then be forced to make decisions about how many skis they will order for the future season, how they will raise the capital, how many salesmen they will use, etc. Then their decisions can be monitored against random weather patterns that are typical of the area in question. The results will quickly demonstrate to the student how complicated the decision making is for running a company.

The great advantage of such simulations is that it does not allow a student to continue to maintain an overly simplistic view about decision making. Frequently they believe one or two variables are important, when in fact, 10 must be monitored to be successful. Going bankrupt has a way of focusing the attention on the additional variables.

Similarly, in some simulations students can be made the head of a nation and given many variables to handle. In most cases, they quickly destroy the population through famine.

(8) Learner Profile. The most interesting new development is presently in the area of a "learner profile." Computers are allowing many of the tests of the past 78 years to be automated. This is significant because it relieves a serious potential social inequality where only the wealthy have access to sophisticated testing for their children. For a long time, dyslexia was a disease of the rich that was known predominantly in such urban centers as New York City and the private school population. Gradually psychologists and testers have spread this knowledge out to a broader sector of the population, but it still is a labor intensive and expensive process to identify and remediate. The computer will allow much fairer treatment of students by automatically testing students of any economic level to identify dyslexia and suggest appropriate remediation. Once a school has a professional computer system,

such testing will be very inexpensive.

The testing will be able to go far beyond the identification of learning disabilities, however, as it will be an invaluable help in identifying hidden talents. Thus testing will have serious career implications as well. The computer has some unique features that allow it to branch quickly, and allow it to get a much quicker fix on a student's abilities in a fraction of the time. The whole new field of "computer adaptive testing" (CAT) is beginning to work with these new test instruments. The computer will also be able to analyze the student's approach to learning, and it may be able to prompt the student to improve his or her approach by suggesting better strategies or relating the learning tasks to specific strengths that the student might not have been aware he or she had.

Once a learner profile is identified, the computer can help coach the individual to improve his or her individual strategies being used in learning. Other areas will also be measured such as right or left brain dominance, individual learning decay rates, and specific memory analysis such as audio retention capabilities. If tests indicate that there are 3 students in the class who have extraordinarily low retention, the teacher might want to train the students to improve this ability, or conversely, to arrange a program, with the help

of computers, that will allow the students to avoid wasting time in sitting and listening to lectures that they cannot retain. Oddly enough, even the brightest students with 100 percent retention sometimes have extremely difficult learning problems as a result of their learner profile. A student with 100 percent audio retention may have difficulty in sorting out the material in terms of importance. Some students with total recall can only do well in tests if they have been able to question the teachers to see what they think is important. Otherwise they lack adequate sorting techniques and have too much material available without knowing what to present as the significant point.

During the next decade the development of sophisticated learner profiles will constitute a fundamental breakthrough in gaining knowledge that would be useful to students, teachers, and families. The great philosophical problem will be how to release the information without falsely labeling students. The troubles that came from talking about IQ's suggests the potential difficulty that this new field might have in releasing information. Semantics are so important for successful implementation. Competency based testing, which limits itself to a discussion of whether or not the student has mastered the materials, has turned out to be extremely useful because there are no connotations about alleged intelligence, etc. The task ahead will be to come up with equivalent approaches

that avoid emotional labeling. WICAT has invested heavily in the development of learner profile packages and expects this to be one of the most fruitful of the new uses of computers.

(9) Computers as a Teaching Language. Computers themselves are introducing a whole new discipline which requires courses to be developed that explain computers, computer languages and computer science. Some of the computer languages have been discussed earlier. They are:

- BASIC
- PASCAL
- FORTRAN
- COBOL
- LISP
- APL
- ASSEMBLER
- C

Each of these languages has certain strengths and weaknesses, and preferably students should have access to learning more than one. A large percentage of any school's curriculum has to do with teaching languages, including the native tongue, to students. Broadly speaking, mathematics is a language as well. Students are taught languages as an abstract set of symbols to give them power in their societies as they

transition to working careers. Computer languages will certainly fit this definition, and so most students should be given an opportunity to learn these languages. WICAT has developed a number of languages for school instruction and will continue to expand its offerings in the future.

(10) Computer Literacy Program. Since most teachers and parents are afraid of computers, the largest initial industry for personal computers is the development of computer literacy programs. These programs help to explain the rudiments of a computer, computer programming, and the general relationship of the computer to society. After the market is saturated with these literacy courses, more serious curricula will begin to be developed. But at the present almost every publisher has a literacy program combining textual material with computer units. They are an important part of the introduction of computers into society, but ultimately this use will not be as valuable as many of the other areas discussed.

(11) Writing and Word Processing Programs. The use of computers to aid writing will be a very important area in the future. These programs will be pushed down to the first and second grade level where touch typing will be taught automatically by sophisticated computer programs. Underlying the writing programs will be strong word processors that will store the student writing and enable the teacher to examine and collect the written materials quickly. Students will be encouraged

to write a great deal more through various prompting programs embedded in the writing curriculum.

Then when the student has completed the writing on the word processor, he or she will be able to make rapid changes without laboriously recopying the paper. Writing productivity should go up dramatically. In addition, the writing programs will link to the English curriculum where the faculty members will be able to comment on errors in the student writing that will assign the students drill and practice in remediation sessions. Thus a student may get written in the margin of his or her paper the letters "CS." The student would input the letters with the theme title, and the computer would come back and explain that the student has made a comma splice error. The student would then automatically be drilled in what a comma splice is until he or she understands it. Should similar mistakes be made in future papers, the computer will comment to the student that he has made the same errors in other papers, and mention these papers by title. The faculty will be left with a record of the types of errors the students are making so that they can track them much more closely as they are changed to new sections during the year. WICAT is well into developing the first total writing package for schools, and it appears that these packages will represent a significant breakthrough in the teaching of writing.

(12) Administrative Programs. Finally, as mentioned earlier, administrative packages will be extremely useful for schools. They will help the administration reduce expensive labor and improve dramatically the accuracy of the records. They will also help in such tedious tasks as scheduling the students, the faculty, and the available physical space. They will also be able to pick up fairly sophisticated patterns such as which students have been cutting school together on a frequent basis. It will also enable administrators to find out what students are failing to meet certain standards so that remedial actions can be taken before the fact rather than after. Furthermore, administrative packages will be linked to instructional programs for special students that are suffering serious disabilities that the district is mandated to help. These are traditionally called Individualized Educational Plans (IEP), and school districts will be helped significantly by automating these records with the help of computers.

WICAT has developed a very broad range of administrative packages from scheduling to IEP units to help school administrators use the new power effectively. These programs run on the same systems that offer instruction, or they can be offloaded on separate machines should the administration prefer this.

VIDEODISCS AND COMPUTERS

The ultimate instructional device will be connecting a videodisc player with one of the powerful new microcomputers. The reason the videodisc, in conjunction with the computer, will be so powerful is that it combines the power of the three most useful instructional technologies:

- the book
- the movie or television format
- the computer

The books greatest asset is that it can store enormous amounts of information for rapid retrieval. The videodisc can store 54,000 pages per side that can be rapidly addressed and held on the color television screen. The videodisc has the additional advantage over a book of being able to incorporate an almost unlimited number of pages as color photographs, color graphs, or straight text. Books become extremely expensive if they incorporate very many color photographs or graphs; whereas, the cost of the color photograph is inconsequential in a videodisc.

The videodisc can also run 30 still frames a second which produce a motion picture or television film on the color television screen. Each side of a videodisc has approximately 30 minutes of motion picture time. For every minute that is not used as motion, 1,800 still frames can be put in. Thus if only 25 minutes of motion picture were implemented, 9,000 still frame pages could be put on

the same side of the disk. Replicating the discs is less expensive than using videotape, and the quality of the image is much higher. The laser videodisc will be the only type of disc player which will have instructional potential. The reason for this is that there are frequently critical individual frames that must be held on the screen for long periods while students are taking instruction. While a videotape device can sometimes find an individual still frame, if that still frame is held for too long a period, the tape will wear out at that point. Also, because of the nature of handling tape, the access time to individual frames can be extremely lengthy. Thus videotape machines will never have the instructional capability that a laser videodisc will. The laser videodisc can hold an individual frame indefinitely without any degradation in quality because the only thing striking the surface of the disc is a light beam from the laser. Thus it can read the same frame indefinitely without wearing it out.

In addition to the rapid access to large amounts of information, the videodisc is extremely powerful for instructional motivation when playing the motion picture segments on the color television screen. Typically, the student will see a motion picture sequence for a few minutes that is highly motivating because of the potential of color, sound, motion, and character identification. Then the disc will take the student into an instructional sequence with still frames under computer control. Here the student is forced to interact with the disk as it asks for answers and then branches to

an appropriate response. This motivational capability that a movie can offer is extremely important for successful instruction.

The computer is needed to add another dimension of intelligence to interact with the student and control the proper sequence of the videodisc material. Thus the computer is the instrument that produces the learner productivity by forcing interaction with the student, giving rapid responses, and branching quickly to appropriate sequences on the disc.

In addition, the new powerful micros have the ability to change information on the discs. They do this by writing an overlay over the videodisc frame being displayed. This ability to add additional information to a fixed frame alleviates the major weakness of the disc, which is its permanency once it is pressed, much as an L.P. record is permanent.

Thus without question, the videodisc, in combination with a powerful microcomputer, is the ideal instruction device. Unfortunately, such a device incorporates the expense of the three technologies as well, that of books, the production of film, and the programming of a computer. This expense can be overcome when the discs are pressed in high volumes, but the school will still have the expense at each workstation of a color television set, a videodisc player, and a computer.

As a result of this individual workstation expense, the videodisc will not be used in great numbers in schools for a few years. Two things should then happen. The price of the videodisc players should come down somewhat, as well as the computers, and schools will begin to get used to the cost of technology which they will factor into their budgets as another useful piece of capital equipment.

Short term, however, schools will probably have one or two players that could be used most effectively for special instruction or testing on limited populations. Such a videodisc configuration could be very useful, for example, in training individual faculty members on the new technologies and computers which are entering their schools. The lesson could be done so attractively that the teachers could learn all about the potential of technology through using it in a very pleasant way.

Another productive use of the videodisc utilizing just a few machines is sophisticated testing for a learner profile analysis. The videodisc, with its capability of using color, graphics, animation and excellent sound, should be able to administer certain test items much more effectively than a standard computer. This should allow even more accurate analysis of individual student learner profile.